

WHAT IS CLAIMED IS:

1. An interferometer for measuring a surface  
shape of an optical element using interference, said  
5 interferometer comprising a reference wave-front  
generating unit for generating a reference wave front  
for measuring the surface shape, which is provided in a  
target optical path, and includes an Alvarez lens.

10 2. An interferometer according to claim 1,  
wherein said Alvarez lens generates a sixth-order or  
higher component of a moving radius of the reference  
wave front.

15 3. An interferometer according to claim 1,  
wherein there are plural Alvarez lenses, the number of  
Alvarez lenses corresponding to the number of orders of  
a moving radius in the reference wave front to be  
generated.

20 4. An interferometer according to claim 1,  
wherein said Alvarez lens generates a fourth-order or  
higher component of a moving radius of the reference  
wave front.

25 5. An interferometer according to claim 1,  
wherein said reference wave-front generating unit

variably generates a fourth-order or higher component of a moving radius of the reference wave front.

6. An interferometer for measuring a surface  
5 shape of an optical element using an interference, said interferometer comprising a reference wave-front generating unit, provided in a target optical path, for generating a reference wave front as a measurement reference for the surface shape, said unit variably  
10 generating a fourth-order or higher component of a moving radius of the reference wave front.

7. An interferometer according to claim 6,  
wherein said reference wave-front generating unit  
15 includes a plurality of optical members, a reference position of each optical member being determined at such a position that aberration generated in said reference wave-front generating unit may be minimized.

20 8. An interferometer according to claim 6,  
wherein said reference wave-front generating unit has a spherical aberration generating part.

9. An interferometer according to claim 8,  
25 wherein said spherical aberration generating mechanism has a plurality of lens members, and adjusts generation

of aberration by adjusting a separation between two of the lens members.

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10. An interferometer according to claim 8,  
5 wherein said spherical aberration generating mechanism has a plurality of lens members for serving as a parallel plane, said optical member being able to adjust a parallel plane.

10 11. An interferometer according to claim 6, wherein said reference wave-front generating unit includes an Alvarez lens.

12. An interferometer according to claim 6,  
15 wherein said reference wave-front generating unit includes:

a mobile part that may variably generate the reference wave front; and

a monitor part for monitoring positional  
20 information of said mobile part.

13. An interferometer according to claim 12, wherein said interferometer uses a moving amount of the mobile part obtained from the monitor part to calculate the wave front to be generated and uses the calculated  
25 wave front for the reference wave front.

14. An interference measurement method for measuring a surface shape of an optical element using interference, said method comprising the steps of:

generating a reference wave front as a measurement reference for the surface shape by using a reference wave-front generating unit including an Alvarez lens;

introducing the reference wave front to a surface of the optical element; and measuring the surface shape by interfering the reference wave front with a target wave front through the surface of the optical element.

15. A method according to claim 14, wherein said reference wave-front generating unit variably generates a fourth-order or higher component of a moving radius of the reference wave front.

16. An interference measurement method for measuring a surface shape of an optical element using interference, said method comprising the steps of:

generating a reference wave front as a measurement reference for the surface shape by using a reference wave-front generating unit for variably generating a fourth-order or higher component of a moving radius of the reference wave front;

introducing the reference wave front to a  
surface of the optical element; and

measuring the surface shape by interfering  
the reference wave front with a target wave front  
5 through the surface of the optical element.

17. A method according to claim 16, wherein said  
reference wave-front generating unit includes a  
plurality of optical members, a reference position of  
10 each optical member being determined at such a position  
that aberration generated in said reference wave-front  
generating unit may be minimized.

18. A method according to claim 16, wherein said  
15 reference wave-front generating unit includes a mobile  
part that may variably generate the reference wave  
front, and

wherein said generating step calculating a  
shape of the reference wave front based on a moving  
20 amount obtained by monitoring positional information of  
the mobile part.

19. An exposure apparatus using an optical  
element manufactured by using an interferometer for  
25 measuring a surface shape of an optical element using  
interference, the interferometer comprising a reference  
wave-front generating unit for generating a reference

wave front for measuring the surface shape, which is provided in a target optical path, and includes an Alvarez lens.

5           20. An exposure apparatus using an optical element manufactured by using an interferometer for measuring a surface shape of an optical element using an interference, the interferometer comprising a reference wave-front generating unit, provided in a  
10 subject optical path, for generating a reference wave front as a measurement reference for the surface shape, said unit variably generating a fourth-order or higher component of a moving radius of the reference wave front.

15           21. An exposure apparatus using an optical element manufactured by using an interference measurement method for measuring a surface shape of an optical element using interference, the method  
20 comprising the steps of generating a reference wave front as a measurement reference for the surface shape by using a reference wave-front generating unit including an Alvarez lens, introducing the reference wave front to a surface of the optical element, and  
25 measuring the surface shape by interfering the reference wave front with a target wave front through the surface of the optical element.

22. An exposure apparatus using an optical element manufactured by using an interference measurement method for measuring a surface shape of an optical element using interference, the method

5 comprising the steps of generating a reference wave front as a measurement reference for the surface shape by using a reference wave-front generating unit for variably generating a fourth-order or higher component of a moving radius of the reference wave front,

10 introducing the reference wave front to a surface of the optical element, and measuring the surface shape by interfering the reference wave front with a target wave front through the surface of the optical element.

23. An interferometer for measuring surface information of a target surface by interfering a reference wave front from a reference mirror with a target wave front from the target surface, said interferometer comprising a reference wave-front

20 generating unit, provided in an optical path for the target surface, for generating a reference wave front as a measurement reference for the surface information of the target surface, wherein said reference wave-front generating unit comprising:

25 a spherical aberration generating part for variably generating a spherical aberration; and

an Alvarez lens part for variably generating a component of six or higher power of a moving radius of the reference wave front.

5           24. An interference measurement method for measuring a surface shape of an optical element using interference, said method comprising the steps of:

dividing a measurement surface of the optical element into at least two segments; and

10           interference-measuring each segment,

wherein in measuring a surface shape, a wave front as a measurement reference for a measurement of at least one segment is an aspheric wave front.

15           25. A method according to claim 24, further comprising a step of an aspheric wave-front generating part approximately independently controllably forming each of fourth-order or higher components of a moving radius of the wave front in the aspheric wave front.

20           26. A method according to claim 25, further comprising the steps of:

approximately independently controlling, in the aspheric wave front, each of fourth-order or higher  
25           components of a moving radius of the wave front; and  
controlling curvature of a spherical component for each segment to be measured.



27. A method according to claim 25, wherein the aspheric wave-front generating part includes at least an Alvarez lens.

5 28. A method according to claim 27, wherein there is a one-to-one correspondence between the Alvarez lens in the aspheric wave-front generating part and a component to be independently controlled.

10 29. A method according to claim 28, wherein the aspheric wave-front generating part controls three components of fourth, sixth and eighth orders of the moving radius in the wave front in the aspheric wave front, and each component is  
15 approximately independently controlled by a corresponding Alvarez lens.

30. A method according to claim 29, wherein an aspheric surface amount controlled by the Alvarez  
20 lenses does not exceed 20 times wavelength of light used for the measurement.

31. An interference measurement method for measuring a surface shape of an optical element using  
25 interference, said method comprising the steps of:

dividing a measurement surface of the optical element into at least two segments; and

interference-measuring each segment,  
wherein in measuring a surface shape, the  
measurement surface is divided into a plurality of  
segments according to a distance from an optical axis,  
5 and a wave front as a measurement reference for a  
measurement of at least one segment is an aspheric wave  
front, and

wherein the aspheric wave front is  
approximately independently controlled in fourth order  
10 or higher components in a moving radius of the wave  
front.

32. A method according to claim 31, wherein  
spherical components in the aspheric wave front are  
15 different for each divided segment, an offset amount  
between the aspheric wave front and a target surface in  
each segment does not exceed 10 times wavelength of  
light used for the measurement.

20 33. A method according to claim 31, wherein each  
of fourth order or higher components of a moving radius  
in the wave front is approximately independently  
controlled by the Alvarez lenses, and an aspheric  
surface amount of each component does not exceed 20  
25 times wavelength of light used for the measurement.

34. An exposure apparatus using an optical  
element manufactured by using an interference  
measurement method for measuring a surface shape of an  
optical element using interference, said method  
5 comprising the steps of dividing a measurement surface  
of the optical element into at least two segments, and  
interference-measuring each segment, wherein in  
measuring a surface shape, a wave front as a  
measurement reference for a measurement of at least one  
10 segment is an aspheric wave front.

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